Essays on the role of frictions for firms, sectors and the macroeconomy

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2 How does demand volatility encourage information and communication technology use? The role of flexibility[1]

2.1 Introduction

The use of information and communication technologies (ICTs) is often thought of as a means to provide firms with more flexibility by reducing the adjustment costs related to changing production factors. Such adjustment costs are pervasive both in the case of capital (Cooper and Haltiwanger, 2006) as well as labour (Hamermesh and Pfann, 1996). Their determinants are manifold, from the policy environment – affecting the degree of financial constraints or employment protection, see Chapter 4 – to purely technological factors such as installation costs or matching frictions. Reducing them allows firms to more closely follow changes in their business environment.

The exact mechanism of how the reduction of adjustment costs is facilitated by ICT is open to debate, however. Some studies suggest that ICT may allow for better planning and management systems to react to changes in a more timely manner (Bartelsman, 2013; Bartelsman et al., 2017). Others focus on the communication enhancing aspect of ICT, which helps maintaining contacts with costumers, suppliers as well as across different plants of the same company (Abramovsky and Griffith, 2006; Bloom et al., 2014). This enables fragmented production structures, which rely more on externally supplied intermediate inputs and less on internal production factors such as employment on payroll and fixed capital.

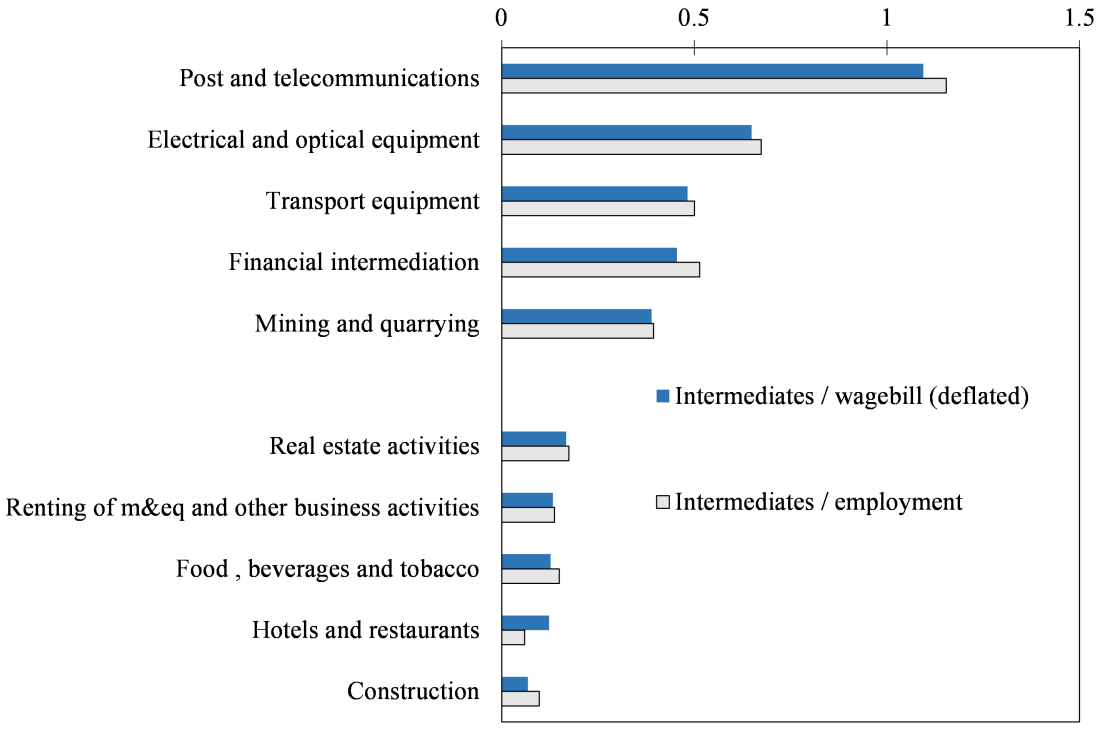
[1]I thank Giuseppe Berlingieri, Flavio Calvino, Chiara Criscuolo, Timothy Destefano, Bart Hobijn, Gabor Pinter and participants at the OECD Applied Economics seminar series for useful comments and suggestions. I am especially thankful for my supervisor Eric Bartelsman for his insights and in helping me getting access to ESSLait data in the context of the project described in Bartelsman and Gal (2014) and which contains the empirical results that rely on ESSLait data and used in this chapter. Granting access to ESSLait data by Statistics Sweden and Eva Hagsten in particular is also gratefully acknowledged.

Extreme manifestations of such business models are recent companies that tend to have only a few employees on payroll or assets in their books, and instead rely on independent ("freelance") contractors or simply people with occasional free time and capacity (e.g. AirBnB for renting apartments, Uber for transporting people, Handy for home cleaning or TaskRabbit for providing help with a wide range of activities.). Closely related to this is the phenomenon what *The Economist* (2015) has labeled "on-demand economy", enabled by the proliferation of smartphone applications and leading to more flexibility in order to match fluctuations in demand.

A simple descriptive plot broadly confirms the idea that more ICT intensive industries rely on a more fragmented production structure: Figure 2.1 shows that these industries have increased more their intermediate inputs (as a ratio of labour inputs, in real terms) over time and on average across 18 OECD countries. The sectors that tend to be the most ICT intensive (such as telecom, manufacturing of electrical and transport equipment) have seen a dramatic rise in the role of intermediates in their production. Put differently, these industries have become more fragmented, and rely less on internal inputs – employment on payroll – and more on goods and services purchased from external sources. At the other end of the spectrum, sectors such as hotels, restaurants and construction – examples for the least ICT intensive industries – have experienced very little if any increases in intermediate use.

The purpose of the chapter is to show that the volatility of the business environment plays an important role in encouraging firms to use ICT more intensively and thus being able to rely more on external inputs to avoid adjustment costs and become more flexible.

Figure 2.1: Intermediate use increases more in ICT intensive industries
Growth in intermediate use for selected industries (1995-2005)



Note: Average growth in real intermediate inputs, normalized by employment or real wages, measured in log points over a ten year period between 1995 and 2005 on a balanced sample of 18 countries (see details in Appendix 2.A.3). Out of the 26 industries, only the top and the bottom five ones in terms of growth in intermediates are shown.
Source: Author's calculations using EU-KLEMS data (O'Mahony and Timmer, 2009).

It uses the idea that firms and industries that are exposed to a more volatile business environment face larger incentives to avoid adjustment costs and rely on flexible inputs. Thus they are expected to make greater use of ICT to help them better connecting and communicating with such "outsourced" inputs. This mechanism, in turn, also induces a positive correlation between ICT intensity and the volatility of outcomes (such as output or employment), since they get more closely related to changes in the environment. Hence the direction of causality between ICT and outcome volatility goes two-ways, and disentangling them is difficult unless exogenous variation either on ICT adoption or the volatility of the environment is available.

The chapter presents new evidence on one direction of causality, showing that turbulence in the external business environment leads to higher ICT intensity. It relies on an exogenous demand volatility measure at the industry level, which is constructed by using input-output links and changes in economic activity in purchasing industries. The dependent variable is a particular type of ICT that captures precisely the type of

communication-related aspects that enable a more fragmented production structure: ordering through computer networks. The positive effect of demand volatility on ICT use is robust to a variety of alternative choices for measuring the type of ICT use (presence of internet, broadband internet or ordering through networks from suppliers), demand volatility, as well as to changing the set of control variables and time periods. Confirming the role ICT plays in enhancing flexibility through relying more on external inputs – measured by intermediate inputs –, separate regression results show that both output and intermediate inputs of more ICT intensive industries follow changes in their demand more closely.

Note that two features of our combined dataset of various sources is crucial for the analysis. First, using an exogenous measure for volatility is key, as ideally one would like to capture the volatility of shocks hitting firms or industries - something which is exogenous to them and not affected by their decisions. However, what we usually observe are outcomes, which are the results of both the shocks and the adjustments given in response to them. If firms and industries are becoming more flexible, the same amount of exogenous business volatility can result in higher observed volatility of outcomes. Second, these indicators are combined with the result of a unique data collection conducted at the firm-level by the involvement of a network of European national statistical offices (ESSnet). This micro-aggregated data retains information on detailed aspects of ICT use, allowing us to focus on and measure the intensity of the communication-enhancing aspects of ICTs.

The chapter contributes to various strands of the literature. First, it enriches our understanding of the relationship between ICT use and volatility. The use of ICT, especially for early adopters, involves experimentation with new business models and organizational structures, thereby leading to more volatile outcomes (Brynjolfsson et al., 2009; Polder et al., 2014; Bartelsman et al., 2016). Adopting ICTs early on can also be viewed as a proxy for innovation and for greater tolerance for risk-taking. These mechanisms emphasize the direction of causality from ICT adoption to increased volatility. At the opposite direction, a more volatile business environment can also encourage ICT use because it can reduce adjustment costs and thus it provides an additional motivation – besides raising efficiency and profits – to adopt ICT. Without refuting the plausibility and the presence of the first set of mechanisms, this chapter establishes the existence of the latter types, by using an exogenous measure of demand volatility built from world input output tables and economic activity in customer markets, adopting the methodology proposed by Shea (1993) and Bartelsman et al. (1994).

Second, this study proposes a specific mechanism about how adjustment costs are reduced by more ICT use. Existing findings on the relationship between adjustment

costs and ICT use are rare. Our proposed mechanism is based on lowering the costs of external inputs which are inherently more costly due to higher communication and coordination costs. Empirically, it is implemented by relying on specific types of ICTs to more accurately reflect its nature as easing the management of external production inputs (the use of data exchange with suppliers and of a fast internet connection). Bloom et al. (2014) also point out that it is crucial to distinguish between the communication enhancing and the information processing aspects of ICT, because they have different implications on the organization of firms. Indeed, Chen and Kamal (2016) find that when ICT investments lower communication costs, both intra- as well as extra-firm trading can increase, depending on the codifiability of production specifications. Our study complements this strand of research by showing that ICT take-up is stronger under more volatile demand conditions, in order to be able to react more promptly to changes in business conditions through relying more on outsourcing. As such, the chapter adds to the set of explanatory factors of outsourcing and offshoring. It has been shown that greater intensity of ICT use leads to more offshoring by Abramovsky and Griffith (2006) for the UK, while confirming evidence is found for Germany more recently by Rasel (2012). Brynjolfsson et al. (1994) confirms that those industries which invest more heavily in ICT tend to have smaller firms afterwards, consistent with the idea the ICT allows to the outsourcing of a wider range of tasks and/or at lower costs.[2]

The chapter is structured as follows. First it outlines the construction of the exogenous demand volatility indicator, followed a brief description of the ICT data used. Then it presents the key result of higher volatility leading to more ICT use. Further, as a means of illustrating the mechanism, it shows that more ICT intensive industries manage to track more closely the movements in demand by their output and intermediate inputs. The final section offers conclusions.

2.2 Demand volatility

Most studies measure volatility derived from economic outcomes such as output (sales) or inputs (employment or wagebill), typically by calculating the standard deviation of their growth rates (Comin and Philippon, 2006; Davis and Heathcote, 2007; Davis and Kahn, 2008). These approaches use observable outcomes at the firm or industry level, hence the volatility patterns derived from them reflect not only the volatility of exogenous shocks but also the nature (speed and degree) of adjustments. Indeed, firms

[2]The role of ICT in enabling an "unprecedented break-up" of the production process has also been emphasized by Grossman and Rossi-Hansberg (2006)

facing a very volatile business environment but at the same time hampered by severe adjustment costs can show a low standard deviation of their outcomes.

In contrast, the distinction between exogenous volatility and outcome volatility is conceptually very sharp and clear in theoretical thinking, allowing theories to provide predictions on how firms react when faced with more volatility or more uncertainty. Therefore, when assessing the consequences of business volatility from an empirical point of view, it would also be important to rely on measures that are exogenous to the firm or industry.

Against this background, this subsection uses input-output linkages at the country-industry level to construct exogenous measures of demand and uses the standard deviation of their growth rates as measures for demand volatility. The idea of using purchasing industries' outcomes as instruments for demand in the supplying industries dates back to Shea (1993) for the US, and it has been refined in Bartelsman et al. (1994) and Baily et al. (2001). The principle has been also used widely in the recent trade literature (Eaton et al., 2011; Bems et al., 2011) in a cross-country context. Here I also apply it in a cross-country setting, and strengthen exogeneity by using cross-country average input-output linkages instead of country-specific ones.

Formally, let $w_{ci}^{c'i'}$ denote purchaser-weights derived from gross output $Y_{ci}^{c'i'}$, which captures the flow of goods going from country c and industry i to country c' and industry i' as a share of total supply produced by country c and industry i (for simplicity, the time index t is suppressed):[3]

$$w_{ci}^{c'i'} := \frac{Y_{ci}^{c'i'}}{\sum_{c',i'} Y_{ci}^{c'i'}}. \tag{2.1}$$

Once these weights are obtained, demand growth Δd_{cit} is calculated as the purchaser-weighted average real output growth rate:

$$\Delta d_{cit} := \sum_{c',i'} w_{ci,t-1}^{c'i'} \Delta y_{c'i't}, \tag{2.2}$$

where lowercase letters indicate natural logarithms, hence Δy and Δd are interpreted as growth rates.

Several restrictions are applied to ensure exogeneity. First, it is standard practice

[3] An alternative method would be to compute these weights by deriving them from the Leontief inverse of the input-output matrices. This would capture the *ultimate links* between industries, taking into account the indirect connections. However, for our present purposes to capture year-to-year volatility, retaining only the *direct* – hence presumably more rapid – links seems more appropriate. Ultimate links are mostly used in the literature when the overall, long-term links are of primary importance (see e.g. the effect of product market regulations on downstream sectors in Bourles et al. (2013)).

to use weights that are dated back in time, hence the time-index $t-1$ of the weights in equation 2.2. In practice, the earliest available weights in the data are used, which refers to the year 1995. Second, and following Baily et al. (2001), those links are set to zero where the *supplier industry* represents a larger share than 5% in the *purchasing industry's* total purchases. This ensures that developments in the supplier industry cannot bear a large impact on its own constructed demand indicator. Finally, we also take into account that industries can potentially choose to specialize in a supply structure that fits their degree of flexibility. For instance, less flexible industries have an incentive to serve such customers that are less volatile. To avoid such a potentially endogenous choice of the supply shares, cross-country averages are used instead of instead of country-specific inter-industry linkages.

As a final step, a rolling window standard deviation of demand growth rates σ^L_{cit} are calculated:

$$\sigma^L_{cit} := \sqrt{\frac{1}{L}\sum_{j=-L/2}^{L/2}\left(\Delta d_{ci,t+j} - \overline{\Delta d_{cit}}\right)^2},$$

where L denotes the length of the rolling window over which standard deviations are calculated and $\overline{\Delta d_{cit}}$ is the average growth rate over the period $[t-L/2, t+L/2]$. This measure is centered at period t, and the window length is set to 6 in the baseline case, while 5 and 7 are also tested in robustness checks. This measure and these window lengths follow closely those used in the literature on measuring volatility of outcomes on annual data (**?**Comin and Philippon, 2006; Davis and Kahn, 2008).

2.3 Data sources and descriptive statistics

To construct demand indicators, we use the World Input Output Database (WIOD, see Timmer et al., 2015) as the source of input-output weights, and gross output or value added from ESSLait (Bartelsman et al. (2017)), which is also the source for specific ICT-type variables (most importantly, the use of networks for purchasing from suppliers). The combination of the two sources gives an unbalanced sample of 14 European OECD countries and 12 industries, with annual data over the period 1996-2010. To obtain measures for industry-level overall ICT intensity, to be used as control variables, the EU-KLEMS database (O'Mahony and Timmer, 2009) is also added. Finally, the analysis is restricted to manufacturing industries, for multiple reasons. First, the degree of heterogeneity within the matched WIOD-ESS services industries is too widespread (e.g. all business services with NACE codes 71-74 are

lumped together). Second, ESSLait does not cover gas, electricity and water utilities (40-42) and construction (45). Third, many important services industries need to be excluded for ensuring exogeneity because their share in *all* of their purchasing industries' total inputs is larger than 5%.[4] See Appendix 2.A for a more detailed description of preparing and combining these sources.

As expected, the demand series constructed in the manner described above show a close but imperfect relationship with actual output, either measured by gross output or value added. Their mean growth rates are very close (2.4 vs 3.4 for gross output and 1.6 vs 1.9 for value added per annum growth rates, see 2.1). The standard deviation of constructed demand is lower, only about 40% (around 6-7 percentage points) of actual output (around 14-16 pp). Their positive comovement is very significant and robust to using gross output or value added as the measure for output (Table 2.2, columns 1-2 vs. 3-4).

Table 2.1: Constructed demand and actual output

1996-2010, 14 countries and 12 industries

		Obs.	Mean	Median	St.dev.	Min	Max
Actual output	Gross output	1,903	0.024	0.039	0.144	-1.331	0.671
	Value added	1,903	0.016	0.026	0.158	-1.393	0.773
Demand	Based on gross output	1,903	0.023	0.035	0.063	-0.401	0.247
	Based on value added	1,903	0.019	0.029	0.071	-0.462	0.296

Note: All variables are annual growth-rates (first-differenced natural logarithms) of real indices. Demand is constructed as described in Section 2.2. The sample covers all manufacturing industries at the EU KLEMS aggregation level (nearly 2-digit detail).
Source: author's calculations using ESSLait and World Input Output Database (Timmer et al., 2015).

[4]Further industry-groups that are prone to these problems are the transport industries (codes 60 to 63) and professional business services (71 to 74), while the wholesale and retail distribution sectors (51 and 52 respectively) are naturally also affected due to their high shares in the total inputs of many industries. The final sample thus retains only manufacturing industries (at the EU KLEMS aggregation level , i.e. approximately 2-digit detail), excluding industry 23 in NACE Rev. 1.1. (Coke, refined petroleum and nuclear fuel). As an extension, the main result is shown to be robust when this sample is extended with the available other sectors: 50 (retail of fuel and motor vehicles), 55 (hotels and restaurants) and 64 (post and telecommunications).

The 14 countries are shown on Figure 2.2.

Table 2.2: Constructed demand strongly affects actual output

1996-2010, 14 countries and 12 industries

	(1)	(2)	(3)	(4)
Dependent variable (actoual growth rates)	**Output**	**Output**	**Value added**	**Value added**
Constructed demand variable based on	Output	Output	Value added	Value added
Demand	1.0645*** (0.1618)	1.0854*** (0.1709)	1.0668*** (0.1247)	1.0670*** (0.1304)
R-squared	0.435	0.461	0.351	0.378
Observations	**1,903**	**1,903**	**1,903**	**1,903**
Fixed effects	country, industry, year	country × industry, year	country, industry, year	country × industry, year

Note: Clustered standard errors (at country x industry level) in parentheses. $***p < 0.01, **p < 0.05, *p < 0.1$. All variables are annual growth-rates (first-differenced logs) of real indices. Columns 1-2 use gross output and columns 3-4 use value added. Demand is constructed as described in Section 2.2. The sample covers all manufacturing industries at the EU KLEMS aggregation level (approximately 2-digit detail), excluding industry 23 in NACE Rev. 1.1. (Coke, refined petroleum and nuclear fuel). Source: author's calculations using ESSLait and World Input Output Database (Timmer et al., 2015).

The relationship between them and actual output volatility is relatively strong, showing correlations around 0.55 and 0.44 for gross output and value added based measures, respectively (Table 2.3). This implies that there is substantial room for either (i) country-industry specific adjustment costs to influence actual output, over and above the exogenous shocks or (ii) other types of exogenous shocks besides demand (e.g. productivity, input costs, etc.).

Table 2.3: Correlations between actual output and constructed demand volatility

*1999-2007, 14 countries and 12 industries**

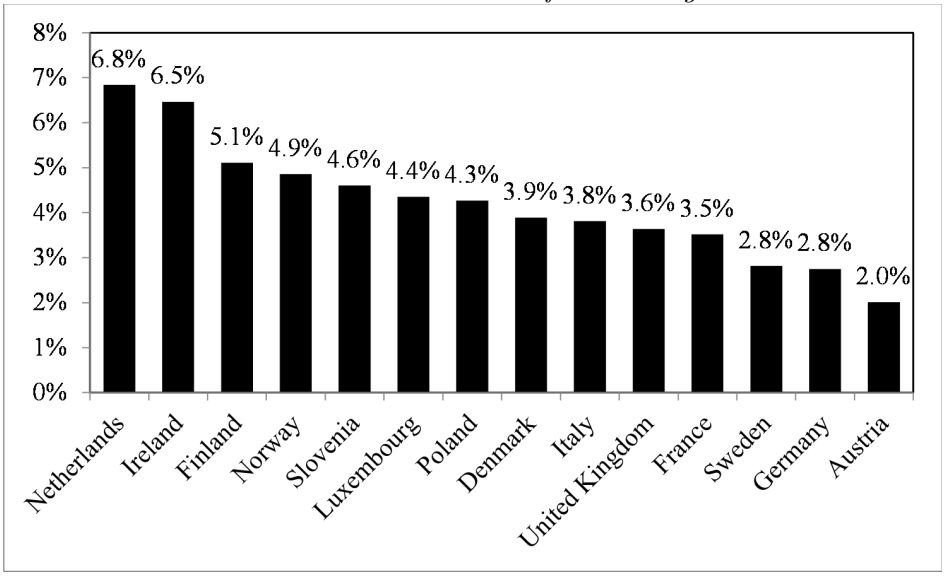
Window length	Gross output based	Value added based
5	0.542	0.443
6	0.545	0.430
7	0.560	0.435

Note: All correlations are significant at 1% level. Demand volatility is calculated as described in Section 2.2 . The sample covers all (12) manufacturing industries at the EU KLEMS aggregation level (approximately 2-digit detail), for 14 OECD countries.
* The actual sample on which the correlations are calculated depend on the length of the volatility window, and 1999-2007 refers to the window length of 6.
Source: author's calculations using ESSLait and World Input Output Database (Timmer et al., 2015).

The cross-country pattern of this exogenous volatility measure suggests that very open and small economies (e.g. Netherlands, Ireland) tend to show more volatility than

large economies (e.g. France, Germany, see Figure 2.2), and this feature is generally robust across the various demand volatility measures.

Figure 2.2: The cross-country pattern of demand volatility
Annual standard deviation of demand growth



Note: Demand volatility is calculated as described in Section 2.2 using a window length of 6 years based on gross output. The country values are predicted values from regression containing country, industry and year fixed effects, averaged by country. The data covers all (12) manufacturing industries at the EU KLEMS aggregation level (approximately 2-digit detail), excluding industry 23 in NACE Rev. 1.1. (Coke, refined petroleum and nuclear fuel) and over years 1997 to 2010.
Source: author's calculations using ESSLait and World Input Output Database (Timmer et al., 2015).

2.4 Regression results on volatility and ICT use

Before turning to regression results, Table 2.4 presents key descriptive statistics. The main ICT measure is "Firm orders via computer networks", which is a type of ICT that can facilitate and automate transactions with external suppliers. It has a mean value of 0.524, implying that in the average industry over our sample, a little more than half of the firms used some type of networks to connect with suppliers, with 0.2 standard deviation, and a wide range of values (the min and max span virtually the whole interval between 0 and 1). Internet and broadband internet connections, however, are much more prevalent and are concentrated near 0.9 for the average industry, with broadband connections showing a bit higher variability.

The main explanatory variable is demand volatility, whose mean shows 0.052 ($\approx$5.2 percentage point) standard deviation of annual demand growth within 6-year windows. The gross output and value added based measures show a similar pattern. A number of standard control variables (such as overall employment, labour productivity and

capital services) are also included, as well as measures for total ICT use, either as a share in total capital services or as volumes. The joint availability of these and the main variables is more limited, however, implying a fall in the sample to about 900 (standard controls) or 600 (ICT controls) from the largest possible sample size of 1,020, resulting from the merge of ESSLait and WIOD.

Table 2.4: Descriptive statistics and data sources

Variable	Total number of obs.	Total number of industries[2]	Mean	Median	St.dev.	Min	Max	Source
*ICT use**								
Firm orders via computer networks	1020	168	0.524	0.542	0.2	0.05	0.946	ESSLait[3]
Firm has internet	1020	168	0.972	0.99	0.057	0.485	1	----
Firm has broadband internet	1020	168	0.845	0.897	0.144	0.302	1	----
Demand volatility								
Output based	1020	168	0.052	0.045	0.029	0.007	0.221	ESSLait (output) and World IO tables[4]
Value added based	1020	168	0.054	0.046	0.03	0.01	0.201	
Control variables[1]								
Employment	1020	168	10.478	10.411	1.266	5.853	13.724	ESSLait
Labour productivity	1020	168	0.776	0.725	0.425	-0.312	2.753	----
Total capital services	864	132	14.573	14.66	1.613	10.398	17.769	----
ICT capital services as share in total capital services	612	120	0.155	0.112	0.164	0.028	1.013	EU KLEMS[5]
ICT capital services (volume)	612	120	5.683	5.695	0.555	3.701	7.243	EU KLEMS

* Average values across firms by country × industry × year

[1] All measured in logs except *ICT capital services as share in total capital services*

[2] Total number of industries across all countries in the sample

[3] ESSnet on Linking of Microdata to Analyse ICT Impact

[4] World Input Output Tables (Timmer et al, 2015)

[5] EU-KLEMS ISIC rev 3 and 4 releases (O'Mahony and Timmer, 2009)

Notes: calculations involving ESSLait data were carried out in the context of Bartelsman and Gal (2014). The sample is restricted to the extent that the main dependent variables (Firms ordering via computer networks) and the main explanatory variables (volatility over 6 years, three period lagged) are all available.

The following regressions explain the adoption of ICTs by demand volatility and a set of controls. They are estimated using ordinary least squares (OLS) with a full set

of country, industry and year fixed effects:[5]

$$ICT_{cit} = \beta\sigma^{L}_{cit} + \gamma X_{cit} + D_c + D_i + D_t + \varepsilon_{cit}, \tag{2.3}$$

where the time index t denotes years , demand volatility $\sigma^{L}_{ci,t}$ uses gross output and is defined over a window length of 6 years dated to $t-3$ so all years that it captures precede the timing of the ICT use indicator (for simplicity, still a time index of t is used). X captures various sets of controls: (i) a set that captures basic characteristics of the industry (employment, labour productivity and capital services) and (ii) two types of controls for total ICT use, either measured as nominal capital services share or in volumes. Their inclusion among the control variables ensures that the interpretation of the demand volatility coefficient is the effect *only on communication type* ICT and not on other types (e.g. computer use *per se* or the use of management software, etc.).D_c, D_i and D_t denote country, industry and year fixed effects, respectively, and ε_{cit} is a standard error term.

[5]Using combined, multiplicative country × industry fixed effects instead of additive ones will be presented as a robustness check.

Table 2.5: Demand volatility leads to more reliance on ICT for external purchases

Dependent variable		Ordering purchases through computer networks					
Explanatory variables		(1)	(2)	(3)	(4)	(5)	(6)
Demand volatility		0.8314***	1.5376***	2.7392***	2.8579***	2.7672***	2.8805***
		(0.2990)	(0.2970)	(0.3726)	(0.3557)	(0.3750)	(0.3559)
Total ICT capital services	As share of total cap.serv.			-0.0684**	-0.0657**		
				(0.0278)	(0.0266)		
	Volume					0.0072	0.0016
						(0.0138)	(0.0147)
Employment			0.0061		0.0219		0.0199
			(0.0143)		(0.0201)		(0.0211)
Labour productivity			0.0221		0.0368		0.0374
			(0.0223)		(0.0239)		(0.0246)
Total capital services			0.0129		0.0109		0.0123
			(0.0090)		(0.0111)		(0.0116)
Country, industry, year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,020	864	612	576	612	576
R-squared		0.768	0.765	0.748	0.755	0.746	0.753
Years		2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010
Countries/Industries		14 / 12	11 / 12	10 / 12	9 / 12	10 / 12	9 / 12

Note: Cluster robust standard errors at country × industry level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Demand volatility is calculated as described in Section 2.2 using gross output and over rolling windows of 6 years. Employment, labour productivity and capital services are measured in logs.

The regression results confirm the positive and significant effect of demand volatility on such type of ICT that is used for dealing with external suppliers, measured by "ordering purchases through computer networks" (Table 2.5). It is robust to all control variable sets. The size of the effect – at around 0.8 in the at the minimum (col. 1) – implies that raising demand volatility from a level prevailing in the lower half of countries to the upper half of countries, in terms of demand volatility – a raise of 2pp, see Figure 2.2 – leads to a 0.8×0.02=0.016 log point stronger ICT take-up. This increase is almost 10% of its standard deviation (0.2, see Table 2.4). As such, demand volatility can potentially explain a sizable portion of ICT intensity.

The qualitative pattern also holds when a broader ICT definition is used. Either any type of internet or broadband internet access is the dependent variable, demand volatility has a significant and positive effect (Table 2.6). Similarly, using an alternative definition for demand volatility – based on value added instead of gross output – leaves the results significant, although in some cases only at the 10% level, once controls for

total ICT use and other industry outcomes are included . The less precise estimates can be the result of a weaker relationship between demand and actual value added than in the case of gross output (see Tables 2.2 and 2.3). Finally, the results continue to hold when the sample is extended to include 3 non-manufacturing sectors for which data is available: retail of fuel and motor vehicles, hotels and restaurants, and post and telecommunication (Table 2.8).

Table 2.7: Demand volatility leads to more reliance on ICT for external purchases

Using value added based demand volatility indicator

Dependent variable		Ordering purchases through computer networks					
Explanatory variables		(1)	(2)	(3)	(4)	(5)	(6)
Demand volatility		0.3345	0.5825**	0.6786*	0.8506*	0.7321*	0.9053**
		(0.2216)	(0.2754)	(0.4032)	(0.4299)	(0.4156)	(0.4440)
Total ICT capital services	Volume			-0.0699**	-0.0722**		
				(0.0272)	(0.0284)		
	As share of total cap.serv.					-0.0040	-0.0066
						(0.0149)	(0.0160)
Employment			0.0116		0.0394*		0.0349
			(0.0158)		(0.0218)		(0.0233)
Labour productivity			0.0246		0.0586**		0.0586**
			(0.0227)		(0.0252)		(0.0256)
Total capital services			0.0108		-0.0004		0.0030
			(0.0098)		(0.0121)		(0.0128)
Country, industry, year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,020	864	636	600	636	600
R-squared		0.759	0.741	0.723	0.726	0.720	0.723
Years		2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010
Countries/Industries		14 / 12	11 / 12	10 / 12	9 / 12	10 / 12	9 / 12

Note: Cluster robust standard errors at country × industry level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Demand volatility is calculated as described in Section 2.2 using gross output and over rolling windows of 6 years. Employment, labour productivity and capital services are measured in logs.

Table 2.6: Demand volatility leads to more reliance on ICT for external purchases

Dependent variable		Having an internet connection						Having broadband internet connection					
Explanatory variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(2)	(3)
Demand volatility		1.1345***	1.4238***	2.3010***	2.3329***	2.2881***	2.3299***	1.3597***	1.7637***	2.1909***	2.2686***	2.1956***	2.2809***
		(0.2464)	(0.2759)	(0.2660)	(0.2638)	(0.2665)	(0.2647)	(0.2588)	(0.3001)	(0.3421)	(0.3314)	(0.3418)	(0.3325)
Total ICT capital services	As share of total cap.serv.			-0.0057	-0.0055					-0.0475**	-0.0450**		
				(0.0106)	(0.0110)					(0.0202)	(0.0210)		
	Volume					-0.0128**	-0.0112*					-0.0105	-0.0123
						(0.0056)	(0.0059)					(0.0121)	(0.0123)
Employment			0.0162**		0.0214**		0.0195**		-0.0080		0.0175		0.0142
			(0.0080)		(0.0095)		(0.0095)		(0.0127)		(0.0140)		(0.0148)
Labour productivity			0.0219**		0.0039		0.0030		0.0400*		0.0051		0.0046
			(0.0099)		(0.0133)		(0.0128)		(0.0237)		(0.0271)		(0.0267)
Total capital services			-0.0067		-0.0059		-0.0042		0.0084		0.0011		0.0039
			(0.0044)		(0.0054)		(0.0056)		(0.0072)		(0.0085)		(0.0090)
Country, industry, year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,044	888	636	600	636	600	1,044	888	636	600	636	600
R-squared		0.632	0.663	0.728	0.740	0.730	0.741	0.815	0.834	0.862	0.872	0.861	0.871
Years		2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010
Countries/Industries		14 / 12	11 / 12	10 / 12	9 / 12	10 / 12	9 / 12	14 / 12	11 / 12	10 / 12	9 / 12	10 / 12	9 / 12

Note: Cluster robust standard errors at country × industry level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Demand volatility is calculated as described in Section 2.2 using gross output and over rolling windows of 6 years. Employment, labour productivity and capital services are measured in logs.

Table 2.8: Demand volatility leads to more reliance on ICT for external purchases

Including an extended set of industries beyond manufacturing

Dependent variable		Ordering purchases through computer networks					
Explanatory variables		(1)	(2)	(3)	(4)	(5)	(6)
Demand volatility		0.6149**	1.3651***	2.5708***	2.8245***	2.6602***	2.8432***
		(0.2773)	(0.2759)	(0.3737)	(0.3527)	(0.3697)	(0.3543)
Total ICT capital services	Volume			-0.0332	-0.0489		
				(0.0329)	(0.0315)		
	As share of total cap.serv.					0.0382***	0.0171
						(0.0132)	(0.0112)
Employment			0.0093		0.0245		0.0218
			(0.0128)		(0.0183)		(0.0182)
Labour productivity			0.0201		0.0118		0.0137
			(0.0144)		(0.0173)		(0.0179)
Total capital services			0.0049		0.0030		0.0041
Country, industry, year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,262	1,060	712	667	712	667
R-squared		0.744	0.744	0.735	0.746	0.740	0.746
Years		2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010
Countries/Industries		14 / 15	11 / 15	10 / 15	9 / 15	10 / 15	9 / 15

Note: Cluster robust standard errors at country × industry level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Demand volatility is calculated as described in Section 2.2 using gross output and over rolling windows of 6 years. Employment, labour productivity and capital services are measured in logs. In addition to the baseline sample of Table 2.5 (manufacturing), the sample is extended to include 3 more sectors outside manufacturing: 50 (retail of fuel and motor vehicles), 55 (hotels and restaurants) and 64 (post and telecommunications).

2.5 Robustness checks

This subsection presents a number of further robustness checks, and all of which confirm the basic finding of higher demand volatility leading to more ICT use. In particular, it holds for (i) using a richer fixed effects structure, with interactive country-industry fixed effects instead of additive ones (Table 2.9); (ii) employing either shorter or longer rolling windows for computing the demand volatility measures than in the baseline (with a window length of 5 or 7 instead of 6, see Table 2.10); (iii) a shorter sample that excludes the financial crisis (2001-2007) (Table 2.11) and (iv) removing potential

outliers (Table 2.12).[6]

Table 2.9: Demand volatility leads to more reliance on ICT for external purchases

Robustness to a richer fixed effect structure

Dependent variable		Ordering purchases through computer networks					
Explanatory variables		(1)	(2)	(3)	(4)	(5)	(6)
Demand volatility		1.0924***	1.7215***	3.5512***	3.1312***	3.5224***	3.0912***
		(0.3483)	(0.3213)	(0.3947)	(0.3762)	(0.3959)	(0.3812)
Total ICT capital services	As share of total cap.serv.			-0.2234**	-0.1887**		
				(0.0886)	(0.0773)		
	Volume					-0.0213	-0.0275
						(0.0812)	(0.0761)
Employment			0.0846**		0.1374**		0.1435**
			(0.0350)		(0.0552)		(0.0554)
Labour productivity			-0.0029		0.0428		0.0405
			(0.0365)		(0.0329)		(0.0348)
Total capital services			-0.0183		-0.0371		-0.0357
			(0.0211)		(0.0514)		(0.0518)
Country X industry, year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,020	864	612	576	612	576
R-squared		0.811	0.803	0.805	0.812	0.802	0.809
Years		2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010
Countries/Industries		14 / 12	11 / 12	10 / 12	9 / 12	10 / 12	9 / 12

Note: Cluster robust standard errors at country × industry level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Demand volatility is calculated as described in Section 2.2 using gross output and over rolling windows of 6 years. Employment, labour productivity and capital services are measured in logs.

[6]Outliers are defined to be the 1% extremes of the distributions (0.5% from the top and from the bottom) of the key dependent variable demand volatility as well as the outcome variable ICT use.

Table 2.10: Demand volatility leads to more reliance on ICT for external purchases

Robustness to changing the length of the volatility window

Volatility window length		5 years						7 years					
Dependent variable		Ordering purchases through computer networks						Ordering purchases through computer networks					
Explanatory variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(2)	(3)
Demand volatility		0.4448*	0.9422***	1.9126***	2.0022***	1.9221***	2.0153***	1.0510***	1.8587***	3.0868***	3.2372***	3.0986***	3.2435***
		(0.2591)	(0.2720)	(0.3253)	(0.3116)	(0.3266)	(0.3122)	(0.3255)	(0.3169)	(0.4193)	(0.3974)	(0.4266)	(0.4004)
Total ICT capital services	As share of total cap.serv.			-0.0874***	-0.0843***					-0.0614**	-0.0604**		
				(0.0270)	(0.0269)					(0.0287)	(0.0262)		
	Volume					0.0005	-0.0007					-0.0028	-0.0103
						(0.0119)	(0.0147)					(0.0148)	(0.0150)
Employment			0.0014		0.0191		0.0151		0.0081		0.0258		0.0231
			(0.0145)		(0.0201)		(0.0211)		(0.0143)		(0.0199)		(0.0209)
Labour productivity			0.0096		0.0334		0.0346		0.0206		0.0305		0.0304
			(0.0215)		(0.0236)		(0.0244)		(0.0231)		(0.0265)		(0.0265)
Total capital services			0.0139		0.0088		0.0118		0.0126		0.0112		0.0136
			(0.0092)		(0.0113)		(0.0116)		(0.0088)		(0.0107)		(0.0112)
Country, industry, year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,140	960	696	648	696	648	876	744	516	480	516	480
R-squared		0.754	0.753	0.737	0.738	0.733	0.735	0.795	0.796	0.783	0.796	0.781	0.795
Years		2000-2010	2000-2010	2000-2010	2000-2010	2000-2010	2000-2010	2002-2010	2002-2010	2002-2010	2002-2010	2002-2010	2002-2010
Countries/Industries		14 / 12	11 / 12	11 / 12	9 / 12	11 / 12	9 / 12	14 / 12	11 / 12	10 / 12	9 / 12	10 / 12	9 / 12

Note: Clustered standard errors (at county x industry level) in parentheses. $***p < 0.01, **p < 0.05, *p < 0.1$. Demand volatility is calculated as described in Section 2.2 using gross output and over rolling windows of 5 or 7 years. Employment, labour productivity and capital services are measured in logs.

Table 2.11: Demand volatility leads to more reliance on ICT for external purchases

Robustness to changing the time period – excluding the financial crisis

Dependent variable		Ordering purchases through computer networks					
Explanatory variables		(1)	(2)	(3)	(4)	(5)	(6)
Demand volatility		2.4211***	3.1069***	3.7776***	4.3084***	3.8520***	4.3593***
		(0.5345)	(0.5034)	(0.5524)	(0.5555)	(0.5441)	(0.5393)
Total ICT capital services	As share of total cap.serv.			-0.0198	-0.0141		
				(0.0333)	(0.0324)		
	Volume					0.0202	0.0207
						(0.0147)	(0.0165)
Employment			0.0034		0.0122		0.0152
			(0.0158)		(0.0218)		(0.0222)
Labour productivity			0.0268		0.0152		0.0197
			(0.0288)		(0.0285)		(0.0281)
Total capital services			0.0150		0.0163		0.0137
			(0.0104)		(0.0127)		(0.0128)
Country, industry, year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Observations		540	480	420	384	420	384
R-squared		0.808	0.798	0.790	0.797	0.791	0.798
Years		2001-2007	2001-2007	2001-2007	2001-2007	2001-2007	2001-2007
Countries/Industries		11 / 12	10 / 12	9 / 12	8 / 12	9 / 12	8 / 12

Note: Clustered standard errors (at county x industry level) in parentheses. $***p < 0.01, **p < 0.05, *p < 0.1$. Demand volatility is calculated as described in Section 2.2 using gross output and over rolling windows of 6 years. Employment, labour productivity and capital services are measured in logs.

Table 2.12: Demand volatility leads to more reliance on ICT for external purchases

Robustness to removing potential outliers

Dependent variable		Ordering purchases through computer networks					
Explanatory variables		(1)	(2)	(3)	(4)	(5)	(6)
Demand volatility		0.8515***	1.5162***	2.6837***	2.7958***	2.8814***	2.8806***
		(0.3054)	(0.2950)	(0.4196)	(0.3964)	(0.3730)	(0.3569)
Total ICT capital services	As share of total cap.serv.			-0.1325**	-0.1153**		
				(0.0528)	(0.0467)		
	Volume					0.0055	-0.0011
						(0.0152)	(0.0156)
Employment			0.0055		0.0240		0.0205
			(0.0144)		(0.0207)		(0.0211)
Labour productivity			0.0190		0.0348		0.0357
			(0.0222)		(0.0251)		(0.0252)
Total capital services			0.0126		0.0098		0.0122
			(0.0091)		(0.0113)		(0.0117)
Country, industry, year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,012	858	598	562	590	571
R-squared		0.767	0.763	0.750	0.757	0.752	0.753
Years		2001-2010	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010
Countries/Industries		14 / 12	11 / 12	10 / 12	9 / 12	10 / 12	9 / 12

Note: Clustered standard errors (at county x industry level) in parentheses. $***p < 0.01, **p < 0.05, *p < 0.1$. Demand volatility is calculated as described in Section 2.2 using gross output and over rolling windows of 6 years. Employment, labour productivity and capital services are measured in logs. These results are obtained when removing outliers, which are defined to be the 1% extremes of the distributions (0.5% from the top and from the bottom) of the key dependent variable demand volatility as well as the outcome variable ICT use.

On a technical note, the standard errors are computed allowing for clustering within each country × industry. They do not change noticeably when heteroskedasticity robust standard errors are used instead.

2.6 The mechanism: ICT allows for more flexibility

This subsection presents further empirical evidence consistent with the mechanism that ICT leads to more flexible responses to shocks, thus providing a motivation to firms to invest in it when faced with a more volatile environment. More specifically, it tests (i) whether the link between output (Y_{cit}) and demand – still measured in an exogenous manner using purchasing industries output growth (d_{cit}) – as well as (ii) between inputs and demand is stronger when firms use more ICT. Formally, it seeks whether the coefficient estimates for the interaction term between demand change and ICT use (γ) are significant and positive in the following regression:

$$\Delta X_{cit} = \beta \Delta d_{cit} + \gamma(\widetilde{ICT}_{cit,t-1} \times \Delta d_{cit}) + \delta ICT_{cit,t-1} + D_{ci} + D_t + \varepsilon_{cit}, \quad (2.4)$$

where X_{cit} is either output Y_{cit} or inputs (labour L_{cit} or intermediates M_{cit}), both measured in logs, and all variable and index notations are as introduced previously (in particular for equation 2.3). The ICT intensity indicator captures again whether firms order their materials through computer networks, and it is averaged over the current and the lagged period (hence the time index $t, t-1$). It is also purged from country*industry and year fixed effects before in the interaction term, so as to minimize the chance that the interaction effect is driven by unobserved nonlinear characteristics of the reactions to demand shocks (hence the notation $\widetilde{ICT}$).[7] The regressions are run on the pre-crisis period so as to avoid the potentially confounding influence of the crisis.

Table 2.13 presents the results, which are consistent with the mechanism that more reliance on ICT leads to a stronger reaction of output to demand shocks (columns 1 and 4). It also stands out that this increased flexibility is achieved via a more amplified response of intermediate inputs (columns 2 and 5). However, it is accompanied by an either insignificant or much smaller change in employment (columns 3 and 6), consistent with the idea that the adjustment-cost reduction channel of ICT operates through a more flexible use of intermediates but less so through employees. These results are robust to using either gross output or value added based demand indicators of the purchasing industries (columns 1-3 vs. 4-6, respectively).

[7] For instance, some countries and/or industries may inherently be more responsive to changes in their demand, and this feature can coincide with being more incentive ICT users. The purging of the ICT indicator from such characteristics prevents that this can drive the result of a positive a significant estimate for γ.

Table 2.13: ICT use leads to more flexibility in reacting to demand shocks

Demand indicator based on purchasing industries' change in:	Gross output			Value added		
Dependent variable (in changes):	Output	Inputs		Output	Inputs	
		Intermediates	Employment		Intermediates	Employment
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Change in demand	0.6361***	0.7012***	0.7366***	0.3700***	0.1640	0.3815***
	(0.1564)	(0.1883)	(0.2302)	(0.1142)	(0.1484)	(0.1289)
ICT intensity × change in demand	**3.4628****	**4.1129****	**1.9690**	**3.2176****	**4.6517*****	**2.7063****
	(1.7002)	**(1.8029)**	**(2.0038)**	**(1.4538)**	**(1.5494)**	**(1.3124)**
ICT intensity	0.0020	0.0092	0.0804*	-0.0149	-0.0127	0.0642
	(0.0541)	(0.0673)	(0.0433)	(0.0536)	(0.0680)	(0.0414)
Country * industry, year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	882	882	888	882	882	888
R-squared	0.381	0.336	0.436	0.368	0.318	0.406
Years	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007
Countries/Industries	14 / 12	14 / 12	14 / 12	14 / 12	14 / 12	14 / 12

Note: Cluster robust standard errors at country × industry level in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Demand change is calculated as described in Section 2.2 using gross output (col. 1-3) or value added (col. 4-6. All change is calculated using first differences of logs on annual data. In the interaction terms, the growth in demand is included as deviations from their means in order to help with the interpretation of the coefficients on the base effects. ICT intensity is purged from country*industry and year fixed effects in the interaction term so as to avoid potentially unobserved factors driving the estimate. The crisis years are excluded from the sample.

2.7 Conclusion

The results of our study show that more volatile, less predictable demand conditions can also motivate why firms choose more flexible types of inputs and try to avoid fixed costs of adjusting. The broader implication is that ICT does not only raise the productive capacity of firms, but it is also a powerful means to adapt to fast-changing business environments. As such, it further fuels the substitution away from traditional types of employment relationships and towards more fragmented production structures, including contractual employment. Also, it adds an extra source of flexibility and productivity at the aggregate level, since resources can be (re)allocated more efficiently across firms. From a policy perspective, this shows that a modern and well-maintained ICT infrastructure is essential. Moreover, the regulation of product markets should be flexible enough to accommodate these new type of business models. Finally, labour market institutions and the education system should be tailored so that employers can

adopt flexible contractual arrangements and employees can face the challenge of more flexibility and potentially higher ICT skill requirements.

Appendix 2.A Data details

The analysis is conducted at the country-industry level, at annual frequency, and is made possible by combining three different country-industry level data sources: ESS-Lait, WIOD and EU-KLEMS. The details of these sources and definition of the variables used from them are detailed below.

2.A.1 ESS Lait

ESSLait stands for ESSnet (European Statistical System Network) on Linking of Microdata to Analyse ICT Impact Search, which is a unique data collection exercise led by the Eurostat and a group of professional academic advisers, with the collaboration of a network of national statistical offices Bartelsman et al. (2017). It collects a rich set of summary statistics at the country-industry-year level (sometimes even further split by productivity or size classes), built up from confidential firm-level databases using the methodology of *distributed micro-data analysis* (Bartelsman et al., 2004). This involves setting up a harmonized protocol (a program code) that is run separately on the database of each statistical office and which produces a database of moments separately for each country. Access to these micro-aggregated data was available only on a restricted basis to specific research projects. The empirical analysis of this chapter was carried in the context of the project described in Bartelsman and Gal (2014).

The most important feature of ESSLait for our purposes is that it contains information from the combination of different firm-level surveys: one on detailed aspects of ICT use (e-commerce surveys) and another one on production- and input use (production surveys). The coverage retained in our analysis for ICT indicators is an unbalanced panel of 14 European countries (Austria, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Sweden, Slovenia and the United Kingdom), 12 manufacturing industries or industry-groups (at the 2-digit level of groups of those, using the classification system ISIC 3) for 1999-2010. Non-manufacturing industries are excluded because most of them are too broad and too important as inputs for other industries hence their exogenous demand volatility cannot be calculated in a credible way. A subset of them is retained in an extension of the baseline result (Table 2.8). We also make use of a third component of ESSLait which covers longer time series – going back to 1995 – on production and input variables ("long panel" database covering Denmark, Finland, France, Netherlands, Norway, Sweden and Slovenia).

The list of variables used from ESSLait and their definitions are as follows:

- ICT indicators (averages across firms within country-industry-year cells):

  - Firm orders via computer networks
  - Firm has internet access
  - Firm has broadband internet access

- Further economic variables (sum of values across firms within country-industry-year cells):
  - Gross output
  - Value added
  - Employment
  - Labour productivity
  - Total capital services

Note that for monetary variables, euro-conversion rates had to be applied for values before euro adoption to avoid level-shifts due to the currency change, for which official conversion rates were used from the European Central Bank. The purpose of the output variables (gross output and value added) is to provide the basis for calculating demand indicators in the supplying industries. Since output price movements are also informative as they at least partially reflect demand developments, nominal output changes are not filtered from price changes (i.e. no deflators are applied to the original, current price values). Labour productivity and capital services are used only as control variables in some specifications, so they are also kept in their original nominal values.

2.A.2 WIOD

The World Input-Output Database is used to construct exogenous measures for demand and demand volatility. It has been developed by a network of research institutes, headed by the Groningen Growth and Development Center (GGDC) in the Netherlands and is documented in Timmer et al. (2015). It relies on national supply- and use tables, detailed cross-border flows of goods and services, and implements a large number of balancing and harmonization steps to assemble an international input-output table for 40 countries and for 35 detailed industries (at the 2-digit level of groups of those, using the classification system ISIC 3), covering the years 1995-2011.

To ensure exogeneity of the production structures, the 1995 structure is used for the average of those 14 countries that are a match with ESSLait. For details on constructing the demand indicators, see Section 2.2.

2.A.3 EU-KLEMS

To provide a control variable for all type of ICT use at the country-industry level, the following variables are used from the EU-KLEMS database (O'Mahony and Timmer, 2009):

- ICT capital services as share in total capital services
- ICT capital services (volume, 1995 = 100)

The 2009 release of the data (more precisely, its 2011 update) covers the years 1970-2007, and is combined with more recent information, contained in the 2012 release (running till 2011), for the following eight countries: Austria, Finland, France, Germany, Italy, Netherlands, Sweden, United Kingdom. The combination is implemented by an approximate conversion table from the industry classification system ISIC4 (used by the 2012 vintage) to ISIC3 (used by the 2009 vintage), following the content of the industry groups and in line with OECD practice used when constructing the OECD STAN database (see Table A.1).[8] For two instances where a one-to-one match was not available, but one ISIC4 industry group covers two ISIC3 ones, the information from the ISIC4 industries is repeated for those two ISIC3 industries. This combination is then matched with ESSLait and the demand indicator derived from WIOD.

Table A.1: Approximate conversion from ISIC Rev. 4 to ISIC Rev. 3 industry groups

Used for combining the 2009 and 2012 EU-KLEMS vintages

ISIC Rev 4 code	ISIC Rev 4 label	ISIC Rev 3 code	ISIC Rev 3 label
10-12	Food	15-16	Food
13-15	Textiles	17-19	Textiles
16-18	Wood and paper	20	Wood
16-18	Wood and paper	21-22	Paper and printing
19	Coke & petroleum	23	Coke & petroleum
20-21	Chemicals	24	Chemicals
22-23	Rubber and plastics	25	Rubber and plastics
22-23	Rubber and plastics	26	Other non-metallic mineral
24-25	Metals	27-28	Metals
28	Machinery	29	Machinery
26-27	Electrics	30-33	Electrics
29-30	Transport eq.	34-35	Transport eq.
31-33	Other	36-37	Other

Source of industry codes and labels: EU KLEMS 2009 and 2012 releases.

[8] I am grateful for Bo Werth and Colin Webb, both from the OECD, for providing information on this.